

When the heaters burned out in the morning there was a dry area about 4 feet in diameter and a frost-free area about 8 feet in diameter, around each heater.

On the second night the heaters were set directly on the surface of the cranberry vines. The "soot arresters" were removed after the heaters had been burning one hour, increasing the rate at which fuel was consumed about three times. After an hour of burning at this rate, the dry area around the heaters was about 6 feet in diameter, and the frost-free area about 10 feet in diameter. An inverted cone, 2 feet in diameter, placed directly over one of the heaters, increased, the diameter of the dry area to 8 feet, and the frost-free area to 12 feet.

The vines in a very small area around the heaters were scorched when the heaters were set directly on the surface of the vines. There was no scorching when the heaters were burned on the tripods. The effective rise in temperature at the surface of the vines, as shown by exposed thermometers laid directly on the vines, averaged

3.6° F. on the second night. The smaller rise was probably due largely to the flame from the heaters being closer to the ground.

The average gain in temperature on the two nights, due to the use of the heaters, was 1.7° F. inside the instrument shelter, and 4° F. on the surface of the vines.

The frost on the two nights of the test caused about 15 per cent damage in the check plot. There was no damage in the plot equipped with heaters.

The fuel oil burned in the heaters cost 6 cents per gallon in barrel lots. The cost of the oil burned was 96 cents per acre per hour with the soot arresters in place, and \$3 per acre per hour without them.

The experiments conducted by Messrs. Wells and Parker indicate that it is practicable to protect cranberries from frost damage by the use of orchard heaters, at a reasonable cost. It is believed that as good or better results can be secured in protecting other low-growing crops, using the same methods.

### SAMPLING THE HIGHER ATMOSPHERE

By W. J. HUMPHREYS

It seems practically certain that the percentages of the several gases of the atmosphere, except water vapor, are very nearly constant from the surface of the earth up to the base of the stratosphere, that is, throughout the layer of considerable convectional mixing. In the stratosphere, however, where convection exists only feebly if at all, and each gas therefore is distributed substantially as it would be if it alone were present, these percentages presumably vary with height, those of the heavier constituents decreasing and those of the lighter increasing.

If this be the actual condition of the stratosphere, as seems highly probable, then the composition and density of the atmosphere at any level in this region readily could be computed if we knew the temperature distribution below that point. Now, the average temperature of the air at every level, from the surface of the earth up to the height of at least 30 kilometers, is well known, season by season, for many places. In the middle latitudes, for instance, the temperature of the air from the height of about 11 kilometers up as far as explored, 30 to 35 kilometers, is around  $-55^{\circ}$  C., varying slightly with the seasons and with the weather in the lower atmosphere. What the temperature, hence also the density, and even the composition, of the air is beyond the levels explored by the registering instruments carried by sounding balloons no one really knows. This temperature may remain substantially constant to the limit of the atmosphere of measurable density. Many have assumed it to do so as the result of a flux of outgoing radiation, practically invariable with height. On the other hand Vegard<sup>1</sup>, at least, has argued from his studies of the aurora, that the temperature of the very high atmosphere, 100 kilometers, and up, above the surface, must be more or less below that of melting nitrogen, or, say  $-225^{\circ}$  C.; and, furthermore, that the higher portions of the atmosphere contain neither helium nor hydrogen, but consist of nitrogen only, chiefly in the form of crystals held up by their state of electrification. Finally, Lindemann and Dobson<sup>2</sup> conclude from their study of meteor data that the temperature of the outer air, 40 to 50 kilometers and beyond, is in the neighborhood of  $30^{\circ}$  C.—tropical heat.

Here then was confusion which, though theory might greatly reduce, only direct observations, perhaps, could fully remove. This confusion remained as bad as ever

until near the middle of 1924, since when it has so greatly yielded as now to be much less pronounced and provoking.

Free hydrogen might, of course, be present in the lower portions of the atmosphere and not in its outermost layers, owing partly, at least, to the presence of ozone, which might oxidize the hydrogen to water vapor, somewhere in the upper air. However, no similar argument applies to helium.

McLennan<sup>3</sup> has shown that the green fluorescent lines of solid nitrogen, produced by electron bombardment, do not coincide with auroral lines, and in particular that, "the" auroral line,  $\lambda$  5577.35, is not so produced, contrary to Vegard's original belief that it was. Furthermore, McLennan and Shrum<sup>4</sup> have shown that this line is produced by an electric discharge through a mixture of air and helium, or oxygen and helium, at low temperature, also at room temperature, and low pressure. Hence the assumptions that there is helium in the upper levels of the atmosphere, and that the temperature of this region is above that of frozen nitrogen, are not only restored to reasonableness, but raised well nigh to certainties.

The logic of Lindemann and Dobson for a high temperature of the atmosphere at the 40 to 50 kilometer level and beyond, also has been questioned. A different line of attack from theirs by Sparrow<sup>5</sup> of the problem of meteor luminescence seems to remove the apparent necessity for any higher temperature in the outer reaches of the atmosphere than that measured hundreds of times and known to obtain at every level from, say, 12 to 30 kilometers.

Perhaps, then, the other horn of our upper air dilemma also is removed. If so it again would seem reasonable to assume that the outer air contains helium, and possibly hydrogen, and that its temperature in middle latitudes is around  $-55^{\circ}$  C.

But however reasonable these assumptions may be they are not known facts. We do not know certainly either the average temperature or the composition of the air beyond levels reached by sounding balloons. This ignorance about the state and condition of our atmosphere is reason enough why we should try to ascertain

<sup>1</sup> Phil. Mag., 46, p. 577, 1923.

<sup>2</sup> Proc. Roy. Soc., A, 102, 411, 1923; 103, 339, 1923.

<sup>3</sup> Toronto meeting of the British Association for the Advancement of Science; and elsewhere.

<sup>4</sup> Proc. Roy. Soc., A, 108, 501, 1925.

<sup>5</sup> To be printed in an early issue of the Astrophysical Journal.

the facts. Besides, the truth in these particulars would aid in the solution of a host of other problems.

There is, then, ample reason for trying to measure the temperature and determine the composition of the outer and as yet unexplored portions of our atmosphere.

A possible general scheme, the details of which might vary greatly, for obtaining these data is as follows:

1. The height will be attained by means of a rocket of the type, say, now being developed by Professor Goddard of Clark University.

2. A highly exhausted, thin-walled, and hermetically sealed tube is carried on or in the head of the rocket.

3. This tube is surrounded by water and a little ice, and the containing vessel more or less thermally insulated from the adjacent air—suggested by a constant temperature device used with balloon pyrheliometers by Abbot, Fowle, and Aldrich.<sup>6</sup>

4. At about the top of the flight the drawn-out tip of the exhausted tube is broken off near its end by a device actuated by the exhaustion of the rocket propellant, or otherwise, as may seem best.

5. As soon as the tube has filled—that is, in a second or two after it was opened, and actuated by the equilibrium between internal and external pressure thus obtained, or otherwise—the tube is again hermetically sealed. This can be done by the short-circuiting of a minute electric cell through a fine platinum wire wound around the drawn-out neck.

The last two suggestions, (4) and (5), are taken from the method successfully used by Teisserenc de Bort in getting samples of air with sounding balloons.

6. At the time the tube is being filled, a flash light of the kind (there are such) that will operate in air of any pressure, however low, is fired. This presupposes that

the air catch is to be made on cloudless nights during the dark of the moon.

7. At two or more suitable stations the flash is photographed amidst the stars with appropriate cameras. This gives, very approximately, the level at which the sample of air was obtained, and is the same scheme as that used by Störmer and others for measuring the heights of auroras.

If all has gone according to plan, and the tube, let down by parachute, or otherwise protected, has been found, we now have a sample of the air taken in at a known height and known temperature, 0° C. (as secured by the ice and water-jacketing of the sampling tube), whatever the surrounding temperature, but unknown pressure. Obviously, however, this pressure, the pressure of the entrapped gas when at 0° C., can be measured at leisure in the laboratory. Furthermore, the constituents of the sample of air, and their relative amounts, are matters of gas analysis of any desired refinement.

A series of such samplings, made at height intervals of 5 to 10 kilometers, would give us the approximate composition of the atmosphere and its pressure at each of various known heights. From these data in turn the corresponding temperatures could be closely computed, since only one distribution of temperature could give, with the known gases, the particular pressures thus found, assuming, of course, that, as shown by Atkinson<sup>7</sup> the pressure of the atmosphere at all levels is essentially of gravitational origin and not appreciably affected by electrification.

Evidently, the observations suggested above would require skill and ingenuity, but they clearly are possible and the facts to be learned highly desirable.

#### PAPERS READ AT THE PORTLAND, OREG., MEETING OF THE AMERICAN METEOROLOGICAL SOCIETY, JUNE 18, 1925

(For other papers presented at the same meeting, see the Bulletin of the American Meteorological Society)

##### WIDE AREA FORECASTING OF STREAMFLOW ON THE COLUMBIA AND COLORADO

By J. E. CHURCH, Director

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West of the Great Continental Divide the United States lives and has its being in its streams.

Three watersheds or series of river systems, arranged in combination like a gothic A, serve this vast region. Dividing between them 1,600 miles from the western apex of the Continental Divide, the Columbia and Colorado flow westward through tributary regions of 237,000 and 225,000 square miles, respectively, to the sea. Connecting them and forming the crossbar of the A, is the Sierra Nevada system furrowed by streams of lesser length but whose combined output exceeds by nearly twice the output of the Colorado.

Contrary to expectation, the relative flow from these three watersheds is Colorado 1, Sierra Nevada 2, Columbia 9, or an annual run-off from the Colorado of 17,500,000 acre-feet, from the Sierra Nevada approximately 32,500,000 acre-feet, and from the Columbia 151,700,000 acre-feet.

Upon the impounding and distribution of these life streams depend the growth and prosperity of the Pacific coast. As a basic factor in their control and maximum use, the Mount Rose Observatory with cooperation from the U. S. Weather Bureau has devoted its energies during the past decade and a half to investigating the possibility of forecasting the seasonal run-off from the streams in the Sierra Nevada and ultimately from the Columbia and Colorado as well.

The possibility of wide-area snow surveying and close forecasting of the subsequent run-off has now been so thoroughly established in the central Sierra Nevada that the city of Los Angeles has adopted the method for its aqueduct in the Owens Basin and for its power projects elsewhere in the Southern Sierra.

Through this action of Los Angeles opportunity will soon be afforded to test the system under extreme conditions of altitude and run-off.

Detailed investigation of the Columbia and Colorado watersheds has revealed the fact that despite their immense areas satisfactory snow surveys and forecasts can be established for each at no greater difficulty and expense than for the joint streams of the central Sierra Nevada. The only new element involved is the higher relative precipitation in summer on the Continental Divide which may affect the run-off beyond the indications of the snow survey and early rains.

The simplicity of the problem is based upon the following peculiarities:

Despite the apparent vast area of their watersheds, these streams are fed in large part by three main feeders that supply from 77 to 87.1 per cent of their total annual flow. Furthermore, the flow in the main stream, based, however, upon short records only, varies less than 11 per cent from the combined flow of the feeders and the extreme variation between even one feeder and the main stream, over a long term of years, has not exceeded 25 per cent. Finally, from 61 to 64 per cent of the entire annual flow occurs during the four months of April-July, due to the fact that the major supply comes from winter snows, which do not begin to melt until late in March. Therefore, a few snow surveys well placed on these main feeders should indicate the amount of water available for the season's crops and industrial needs.

Furthermore, they will indicate the danger of spring floods from the upper streams and in case the reservoirs are maintained at maximum level, as must be the case when the water is put to maximum use, the reservoirs can be eased down to prepare storage for flood waters rather than permit the streams to flow full volume over the crests and menace the lands along the lower stream.

Fortunately, the winter floods that traverse western Oregon and Washington come mainly from the Cascades and find ready escape in the huge channel of the Columbia, which in the winter flows only at minimum stage because of the dormant snows on its main watershed.

<sup>6</sup> Smithsonian Miscellaneous Collections, Vol. 65, No. 4, 1915

<sup>7</sup> Proc. Roy. Soc., A 106, 429, 1924.